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BOOK REVIEWS

Radiation Protection in the Mineral Extraction Industry (NCRP Report No. 118)

National Council on Radiation Protection and Measurement : Maryland, USA, 1993

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General :

The report covers exhaustively the various aspects of the sources of exposure in the mineral extraction and beneficiation industry and concomitant radiological safety of the worker, public and environment.

The subject matter is covered in nine chapters and two appendices. However, the report does not conform to the latest recommendations of the International Commission on Radiological Protection (ICRP). Given below is a chapterwise review of the report.

Chapter 1 : Introduction

The purpose of the report is given as to describe the vital parts of an effective radiation safety programme for mineral extraction and processing of ores *viz.* mining, milling and beneficiation. These have come increasingly under scrutiny from society concerned about occupational and environmental risks. The report is so written that it can be used by any individual with a basic technical background. The concepts of radiation protection are explained and the scope of the report is given as the description of basic principles of radiation safety as applied to design and operations of mining, milling and beneficiation facilities. The importance of maintaining exposures as low as reasonably achievable (ALARA), economic and social factors being taken into account, is emphasized.

Chapter 2 : Design of Radiation Protection Programmes

This chapter emphasizes the need for making responsible decisions about the level of radiological control appropriate to a given facility. The radiaiton safety programme should be designed to limit risks to employees and members of the public to levels comparable with risks from other common contributors to risk. Commitment of the management to safety should be expressed through adequate provision of human and financial resources to implement programmes successfully, instilling in employees an awareness of their own responsibility for safety and an evaluation of programme effectiveness on an ongoing basis. The report emphasizes the need for imparting proper training to the supervisory and lower

level staff to create the right safety awareness in them including informing the management of any unsafe practices/situations which may need attention.

A Radiation Safety Officer (RSO) should be employed in mineral extraction facilities where exposure pathways are complex and difficult to control. The RSO should report to the senior management and should have the authority to enforce radiation safety regulations and administrative policies at all levels of the Organisation. Where potential radiation exposures reach dose limits, it may be advisable to appoint a radiation safety committee to help. Proper records should be generated and retained. These will include :

1. Complete information on radiological conditions at the facility *viz* radiation and surface contamination surveys, airborne radionuclide measurements and radioactive material inventory and disposal.

2. Complete evaluations of radiation exposures of workers and visitors including the bioassay data.

3. Evaluations of radiological impact on the environment including environmental modelling and measurements.

4. Programme implementation documentation.

A quality assurance programme, to provide confidence among managers and periodic auditing of the radiation safety programme to evaluate its effectiveness are other suggestions.

Chapter 3 : Sources of Potential Radiation Exposures

The principal sources of radiation exposure in the mineral extraction industry are connected to the uranium (^{238}U) and thorium (^{232}Th) series In mines the sources of radiation exposure would include external gamma radiation and airborne radon, radon-decay products (progeny) and ore dust containing radionuclides. Of these radon is the most singificant one. Milling can result in elevated concentrations of various radionuclides at different stages of the process. Petroleum products, natural gas deposits and several minerals also have uranium and thorium associated with them. This chapter has a quantitative listing of such minerals, products and byproducts and wastes.

External radiation levels in most mines are low but can reach upto 1 mGy/h in uranium mines in selective deposition or exceptionally rich ore boides. During ore-working and processing, concentrations of specific radionuclides can increase and so also the radiation levels. Such situations also provide exposure to airborne radioactivity through inhalation. Dust particles may contain ^{238}U, ^{234}U, ^{235}U, ^{228}Th, ^{230}Th, ^{232}Th, ^{226}Ra, ^{224}Ra and ^{210}Po. Transferable surface contamination can be a source of inhalation and ingestion of radioactive materials.

The chapter discusses the releases to the environment through the air and water routes. Mine ventilation discharges, exhaust stacks, high temperature procedures of calcining or sintering and emissions from ore stockpiles, all can lead to airborne emissions. Similarly

release of radioactive effluents to water bodies can occur due to a host of sources such as mine dewatering, aqueous effluents from ore crushing and sorting efforts, mill waste water processing, raffinate and tailing transport and disposal, process vessel and piping rupture and retention system failures.

Exposure potential of any product, process by-product or waste materials should be defined and coordination with appropriate regulatory authority is advised because the regulatory practices may be changing.

Chapter 4 : Exposure Management Programme

This chapter deals with the limiting of exposure below the recommended limits at the design stage itself, taking into consideration equipment, operations and operations time. The recommended upper limit of effective dose for workers is 50 mSv per annum and 10 mSv multiplied by the individuals age in years as cumulative effective dose. For members of the public exposed frequently, the limit is 1 mSv per annum and for those not exposed continuously or frequently it is 5 mSV. This distinction at such low doses is rather strange and not in conformity with ICRP philosophy. Of course the principle of optimisation namely "of as low as reasonably achievable" (ALARA), economic and social factors being taken into account is to be applicable and limits include both internal and external exposures.

The exposure potential varies significantly across the different minerals extraction operations and depends upon factors such as geological formations; type, distribution and quantity of ore; and mining and processing methods. Exposure potential is greater in underground uranium mining Mines bearing high grade uranium ores (20 to 30% UO_2 have gamma exposure ratio as high as 1 mGy/h or greater and beta radiation dose in air near the ore surfaces may be ten times the gamma dose but is less important. But the lower limit on for whole-body exposure as opposed to skin exposure means that gama irradiation is more important than beta irradiation in defining exposure control measures in mines. The ore processing activity is such that wide variations in radiation levels may occur. Therefore, due consideration should be given to storage places of yellow cake and various plant residues such as ^{226}Ra and decay products. Inhalation of uranium dust could be a potential hazard in mining operations but the most important source of exposure is from radon decay products. Radon concentration in air is as low as 0.008 Bq/1; but in mine it could be two orders of magnitude higher and the daughter products which give dose essentially to bronchial tissues could build upto hundreds of working levels (WL-one working level is any combination of short lived radon daughter products in one litre of air that will result in the emission of 1.3×10^5 MeV of potential alpha energy of 2.08×10^{-5} joules of energy). Thus the entire mineral extraction and beneficiation operation is to be planned considering the geologic, hydrogologic, meteorologic factors of the area and the concentration of active material in the ore body. Accordingly ventilation in the mining area, facilities for effluent discharges from

the mine and the tailings pond, *etc.*, are to be provided. Proper ventilation in the mines, suitable effluent treatment, care and surveillance of the tailings pond are very important.

General radiation safety measures to be intorduced are (1) access control with barriers and placards, (2) material control at every stage, (3) proper waste management and (4) good housekeeping in addition to the use of personnel protective equipment. On the use of respirators this report is cautions as their use increases the risk of physical injury. However, the use of respiratory equipment in special circumstances (ventilation failure, high radon concentration areas, yellow cake dryers *etc.*) is recommended.

The training of workers is duly emphasized and includes all details about the radiation, how exposures may occur, nature of work places, effects of radiation, protective equipment, individual's and managements' responsibility and emergency procedures. Due consideration in imparting training is also suggested for the employees' educational background and position in the organization.

Chapter 5 : Monitoring of Occupational Exposure

Radiation monitoring comprises two broad categories, *viz.* (a) characterisation of the work areas, (b) assessment of personnel exposures.

Characterisation of work area involves survey of work areas for external radiation, surface contamination and air activity. Integrated air sampling and measurement of general radiation background over extended periods using passive monitors are required. Additional control measures, respiratory protection, stay times *etc.* are identified

Assessment of personnel exposures includes, besides estimation of internal and external dose, identification of task related exposures. The Report gives a model monitoring programme and gives details of instruments required for survey work and the badges required for personnel monitoring. The importance of ^{222}Rn and progeny in characterising work places, in particular mills, is duly emphasized. However, it must be added that ^{220}Rn and progeny constitute a significant portion of the total dose in all processing units for thorium because of their shorter half-lives.

It may be pertinent to mention that no loose contamination should be permitted on tools, equipment, *etc* leaving the controlled area. It may also be more appropriate for the regulatory authority to stipulate the limits for contamination. The nature of work in mines and mills involves airborne contamination and consequent inhalation and internal contamination. Therefore, bioassay for internal dose assessment becomes very important and the report gives good coverage to the bioassay requirements.

Chapter 6 : Effluent Monitoring and Environmental surveillance

This chapter emphasizes the need for the collection of baseline data at least for one year prior to the start of operation. Environmental exposure pathways both through the air and the water route are well covered. The monitoring of effluents will depend upon the

proximity of population. However, samples from release points should be regularly taken and tested. Also there should be a programme to determine the fate of the released pollutants. The chapter gives the objectives of environmental surveillance and details of programme design covering the different matrices and pollutants required to be watched.

Chapter 7 : Guidelines, Standards and Regulations

This chapter, besides discussing the general concepts on guidance and standards, gives information on the various agencies and the corresponding regulations, under which different aspects of the mining and milling work fall in the United States of America. Specific numerical limits are omitted to ensure that this report does not become outdated. Nevertheless keeping uptodate with the limits is important and the managements should be in the know of the latest recommendations. The above conditions will also be applicable to our country and both the regulatory agencies and the affected parties should have an arrangement in this regard.

Chapter 8 : Radiation Emergency Response Planning

This chapter emphasizes the need for the managements of mining operations to be prepared to deal with accident situation that may arise during operations, or transportation

Chapter 9 : Radiation Protection in Specific Applications

This chapter discusses the "non-conventional" methods of production operations such as "heap-leaching" extraction by the application of liquid leaching agent on ore body or "*in*-situ" mineral extraction by injection of leaching agent in mines or as "side-stream extraction" as in uranium recovery during phosphoric acid/fertilizer production These operations present much less occupational exposure but environmental monitoring is important.

May be because of the local importance, while uranium extraction is dealt with quite extensively the coverage of thorium and rare earth (RE) extraction is inadequate. In the separation of thorium from RE ^{228}Ra, in contrast to ^{226}Ra as in uranium extraction, has a lower half-life and poses high external radiation problem from the non-thorium fraction. For the same reason handling of thorium poses greater problem due to thoron buildup in equilibrium quantities with short half lives. Gamma and beta radiation in the thorium decay series also pose external exposure hazard not known in the handling of uranium.

V K JAIN
Reactor Safety Division,
Bhabha Atomic Research Centre, Bombay-400 085

P P V J NAMBIAR
Radiological Safety Systems Division,
Bhabha Atomic Research Centre, Bombay-400 085

Principles of Statistical Radiophysics

by S M Rytov, Y A Kravtsov and V I Tatarskii

Vol I (Elements of Random Process Theory), 1987
(Translated from the Russian by A P Repyev)
x+ 253 pages, 28 figures, price DM 124 00 (Hard cover), ISBN 3-540-12562-0
Vol II (Corelation Theory of Random Process), 1988
x+ 234 pages, 54 figures, price DM 148 00 (Hard cover) , ISBN 3-540-16186-4
Springer Verlag Berlin-Heidelberg-New York-London-Paris-Tokyo

The monograph consists of four volumes of which two volumes (vol I & II) are reviewed. Going through the contents of the books one cannot help stating that they bear the testimony to the heritage of Russian analytical minds. The lucidity of presentation enriched by illustrative examples and problems relevant to the physical phenomenon like wave propagation in optical and radio frequency region, oscillation (acoustic and electromagnetic), non-thermal and thermal radiation enhances the avidity of a reader.

The genesis of the word "Radiophysics" in the title of the monograph is ascribed to L. I. Mandelshtam's principle of "Isomorphism of Laws" which implies that laws discovered in various branches of physics are under appropriate conditions applicable to other fields. This was precisely invoked by Lord Rayleigh in his studies on phenomenon of Linear optics and acoustics. The authors have made dauntless effort to bring out systematically and in unified manner the statistical aspects of wave-process in material media.

Vol I of the monograph deals with elements of random process theory. The introductory chapter is a lucid elaboration of the motivation and contents of chapters to follows

In chapter 1, the authors develop the classical concepts of probability, distribution law for random variables The Binomial distribution law and its two asymptotic forms *e.g.* Poisson Laplace distribution and Gaussian distribution are revisited in an inimitable way

Chapters 3 and 4 are concerned with random pulses with a generalized version and the Central Limit theorem. The random functions are introduced to develop the theory of Markov process, correlation theory and ergodic aspect of random processes.

Markov process for discrete states, transition to continuum set of states, application to Rayleigh distribution, Fokker-Plank-Einstein equation, vacuum-tube oscillator and Brownian motion and finally Kolmogorov-Feller equation are the covering topics of chapter 5.

In chapter 6, Stochastic differential equation (for random function) are obtained with illustration in first-order equation. This equation is then generalized for random action with arbitrary distribution law.

Vol II of the monograph is a thorough and erudite presentation of correlation theory for random processes. "Correlation" is of central importance to "fluctuation" unfolding the physical significance of a wide class of phenomenon including Brownian motion, White noise, Blackbody radiation, thermal noise in quasistationary networks *etc.*

In chapter 1 the analytic signal theory of Gabor for complex random function, spectral representation of random functions with illustrations are discussed.

In chapter 2, the spectral correlation on white noise and black body radiation (Plank's formula) correlation of coherence of electromagnetic radiation with reference to celebrated Young-Rayleigh interferometer and Wolf's analysis on amplitude correlation and Hanberry Brown and Twiss Intensity correlation (fourth order in amplitude) on Radio interferometer are beautifully discussed.

In chapter 3, the spatial theory of random action (having a temporal representation) on dynamical systems have been developed with a view to analyse thermal noise in quasistationary networks (Nyquist formula) leading to the celebrated fluctuatin dissipation theorem of Callen. The thermodynamical and electromagnetic aspects have been extensively discussed in the concluding section (3.6) with reference to realistic problems.

Chapter 4 is devoted to the analysis of non-stationary process The Flicker effect (discussed by Johnson) a typical fluctuatioal noise in radio engineering is discussed critically.

The spectral analysis for non-stationary process led to the power spectrum. In the concluding section, varieties of model processes are discussed through solutions of problems.

The references for each chapter of vol I and vol II are exhaustive and up-to-date (till 1988).

HARIPADA ROY
Department of Physics,
Jadavpur University, Calcutta-700 032
P K MUKHERJEE
Department of Spectroscopy,
Indian Association for the Cultivation of Science,
Jadavpur, Calcutta-700 032